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GROUND WATER RESOURCES OF THE LANSDALE AREA, PENNSYLVANIA

By
Donald R. Rima

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U. S. GEOLOGICAL SURVEY

Prepared by
The United States Geological Survey
Ground Water Branch
in cooperation with
The Pennsylvania Geological Survey

DEPARTMENT OF INTERNAL AFFAIRS
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GROUND-WATER RESOURCES OF THE LANSDALE AREA, PENNSYLVANIA

BY

DONALD R. RIMA[1]

INTRODUCTION

The Borough of Lansdale for the past 50 years has obtained its supply of water from wells, and until the late summer of 1952 had experienced no serious shortage. As additional supplies were needed new wells were installed, without detailed knowledge of the depth of the aquifers to be tapped or the yield to be expected. The purpose of this investigation, made with the assistance of the Lansdale Municipal Authority, was to identify the sources of recharge and to describe the occurrence and movement of ground water in the Lansdale area. The results are described in this report, and it is hoped that the information presented will aid in the development of additional water supplies for all purposes.

Data on which this report is based were collected as part of a detailed study of ground-water conditions in the rocks of Triassic age in southeastern Pennsylvania. This and similar ground water investigations in Pennsylvania are made by the United States Geological Survey in cooperation with the Pennsylvania Geological Survey.

LOCATION

The area covered by this report comprises approximately 25 square miles in north-central Montgomery County, Pennsylvania. (See fig. 1.) It includes the boroughs of Lansdale and North Wales, and parts of the sur-

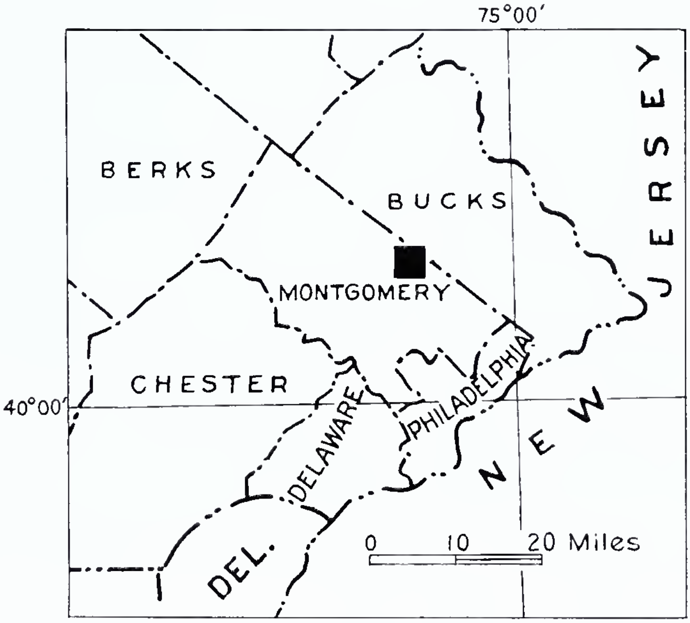


FIGURE 1. Index map of area covered.

[1] Geologist, U. S. Geological Survey, Ground Water Branch.

rounding townships: Hatfield, Montgomery, Upper Gwynedd, and Towamencin. Lansdale is approximately 25 miles northwest of Philadelphia, 30 miles southeast of Allentown, 40 miles east of Reading, and 35 miles west of Trenton, New Jersey. The Lansdale area is served by the Doylestown and Bethlehem branch lines of the Reading Railroad Company, which provides commuter service to Philadelphia in addition to regular freight and passenger service. U. S. Highways 202 and 309 and State Highways 63, 363, and 463 provide convenient routes of transportation by automobile from all directions. The northeast extension of the Pennsylvania Turnpike system now under construction, will pass Lansdale a short distance to the west.

The Lansdale area has a population of slightly more than 20,000. About half this number lives within the borough limits of Lansdale. The most striking cultural feature of the area is the diversification of its industries. More than 200 industrial plants employing more than 8,000 people are located within the area. The list of industries includes foundries, steel fabricators, textile mills, furniture manufacturers, and television tube manufacturers, to name but a few.

PHYSIOGRAPHY

The Lansdale area is situated within the Piedmont physiographic province (Fenneman, 1938). The Piedmont is a gently sloping upland ranging from an altitude of about 900 feet above mean sea level at the foot of the Appalachian Mountains to the northwest, to about 50 feet above mean sea level at the inner edge of the low-lying, almost featureless Atlantic Coastal Plain to the southeast. Relief in the Piedmont is in part the result of differential weathering of the underlying bedrock and in part a consequence of erosion by the major stream systems draining the plateau.

The Lansdale area occupies a position remote from the major streams. Land-surface elevations range from about 200 feet to about 500 feet above mean sea level. The relief of the area is believed to express closely the relative resistance to weathering of the underlying bedrock. The more resistant strata form northeast-southwest trending ridges whereas the less resistant strata underlie the intervening lowlands. The lowlands, though less conspicuous, occupy the greater part of the area.

The area is drained by tributaries of the Delaware River. The southern two-thirds of the area is drained by Wissahickon and Towamencin Creeks, which flow southwesterly and empty into the Schuylkill River, the largest tributary of the Delaware River. The northern third of the area is drained by Neshaminy Creek, which flows northeasterly for a short distance and then turns to the southeast, emptying directly into the Delaware River between Philadelphia and Bristol. Drainage patterns generally trend northeast-southwest, parallel to the principal topographic features, but where the ridges are breached the streams flow southeasterly.

GEOLOGY

The rocks that underlie the Lansdale area are of Triassic age. They form part of the sequence of sedimentary and extrusive igneous rock for-

mations named the Newark group, for exposures in the vicinity of Newark, New Jersey. These formations are exposed in a belt extending from the Hudson River southwestward through New Jersey, Pennsylvania, and Maryland into Virginia. They consist of alternating layers of shale and sandstone having a maximum aggregate thickness greater than 18,000 feet (McLaughlin, unpublished manuscript). The beds have been tilted to the northwest on a northeast-southwest trending axis parallel to their belt of outcrop, and their upturned edges have been beveled by erosion. In many places the rocks have been displaced by faulting and distorted by folding. Igneous rock in the form of dikes, sills, and lava flows are associated with the Newark group.

The Newark group is divided into three formations named, from oldest to youngest, the Stockton formation, the Lockatong formation, and the Brunswick shale. Only the latter two are tapped by wells in the Lansdale area and hence only these are described below.

LOCKATONG FORMATION

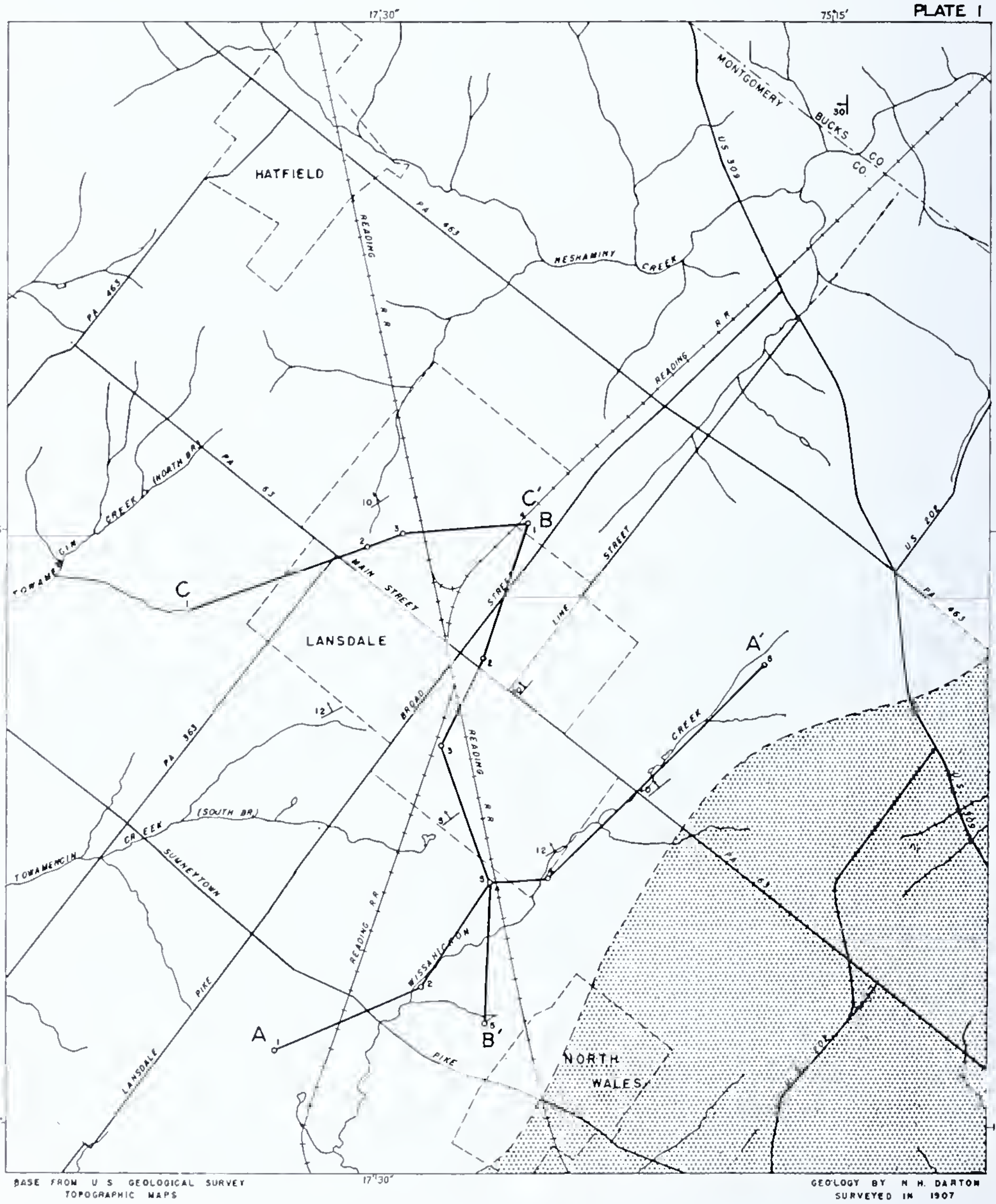
The Lockatong formation has a maximum stratigraphic thickness of about 4,000 feet in southeastern Pennsylvania (McLaughlin, unpublished manuscript) and consists mainly of hard shales and compact sandstones that are characteristically dark colored, fine grained, and well cemented. It crops out at the land surface in the southeastern corner of the Lansdale area and forms the prominent ridge trending northeast from North Wales. (See Plate 1.) The formation dips northwestward beneath the Brunswick shale at an angle of about 10 degrees. It contains very few fractures or other types of openings and, consequently, yields little water to wells. The rocks of the Lockatong formation are much more difficult to drill than those of the overlying Brunswick shale.

BRUNSWICK SHALE

The Brunswick shale has a maximum stratigraphic thickness of about 9,000 feet in southeastern Pennsylvania (McLaughlin, unpublished manuscript) and consists mainly of soft red shale interbedded with reddish-brown sandstone and siltstone. Some of the shales are sandy or silty, and there are some beds of gray, brownish, and greenish shales. The beds are thin and the bedding planes are irregular and discontinuous, making it extremely difficult to trace a selected bed more than a few tens or hundreds of feet. The shale is fractured in many places and some of the fractures are filled with calcite, a mineral composed of calcium carbonate.

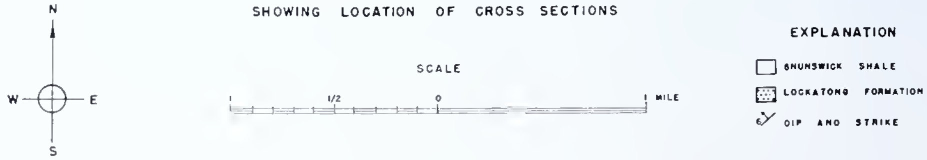
Wherry (Bascom, et al., 1931, p. 30, 31) noted small cavities in several exposures of beds in the Brunswick shale which he thought were formerly occupied by the mineral glauberite (a double sodium-calcium sulfate). Calcareous concretions the size of marbles also have been noted in the Brunswick (Bascom, et al., 1909, p. 8). Some of the thin beds of sandstone in the Brunswick appear to have been cemented partly by calcite soon after deposition. Thin layers that appear to be limestone conglomerate, limestone pebbles in a shaly matrix, occur in the Brunswick shale in the Lansdale area. Solution openings occur in the rocks wherever they

PLATE 1



GEOLOGIC MAP OF LANSDALE AND VICINITY, PENNSYLVANIA

SHOWING LOCATION OF CROSS SECTIONS



contain soluble material accessible to circulating ground water, and as a result some beds have an almost cellular appearance. (See fig. 2.) These zones yield moderate supplies of water to wells when tapped where they lie below the water table.

GROUND WATER

Principles of Occurrence

Water that occurs beneath the land surface moves through and is stored in the numerous openings in the rocks of the earth's crust. Most rocks have many small openings in the form of pores or crevices, and some have larger openings, such as caverns and open fissures. Below a certain depth all the interconnected openings are saturated with water that is free to move by gravity to wells. The upper surface of the zone of saturation, when not formed by an impermeable body, is called the water table, and the water in the zone is referred to as ground water. The amount of ground water available in any area is controlled by the porosity and permeability of the rocks in the zone of saturation.

A rock formation that will yield ground water in sufficient quantity to supply pumped wells or springs is called an aquifer. Ground water may occur under confined or unconfined conditions. If ground water is not confined, it is said to occur under water table conditions, and the water level in a well marks the top of the saturated zone, or water table. If confined between relatively impermeable strata, ground water is said to occur under artesian conditions, and in tightly cased wells the water level rises above the top of the aquifers they tap. The imaginary surface to

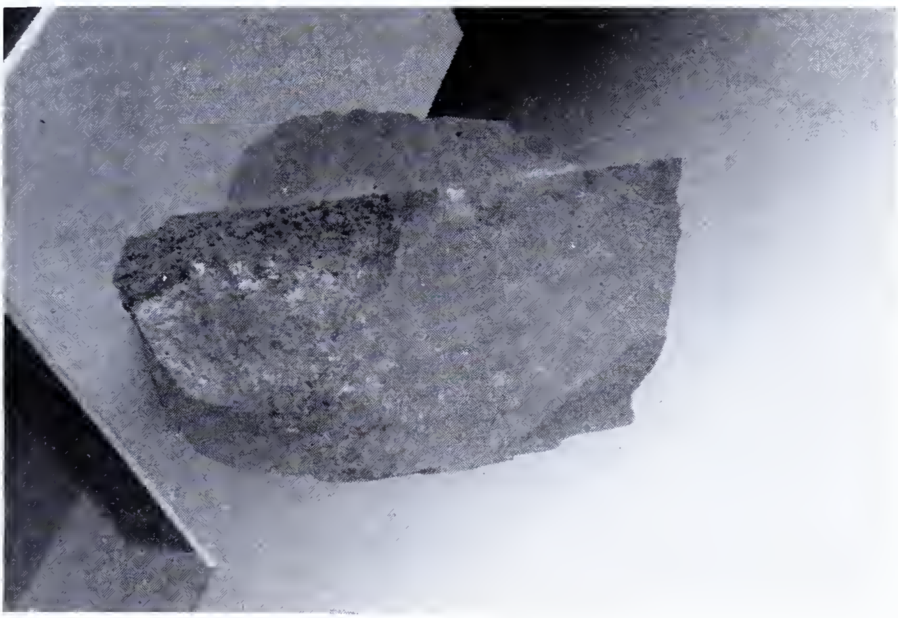


Figure 2. Specimen of the Brunswick shale showing the effect of solution of calcareous material

which the water in an artesian aquifer will rise is called the piezometric surface, and it indicates the pressure head of the water in the aquifer.

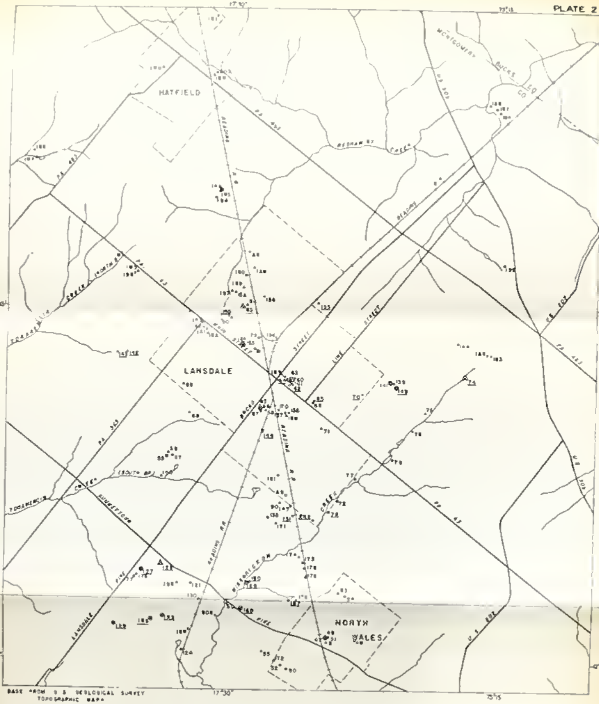
Ground water moves by gravity from intake areas toward areas of lower head, and ultimately to points of discharge. The direction of movement is determined by the slope of the water table or the piezometric surface. The flow of ground water is through openings in the rocks and because these openings are usually small and tortuous they offer considerable resistance to the movement of the ground water. Consequently, the rate of movement of ground water is very slow compared to that of surface water, and generally it can be expressed in feet or even fractions of a foot per day.

The ultimate source of fresh ground water is precipitation. Water falling on the land surface either runs off in streams, sinks into the ground, or evaporates into the atmosphere. Of the part that sinks into the ground, some migrates down to the water table and enters the zone of saturation. As more water is added, the water table rises, reflecting the additional volume of water in storage. Under natural conditions the amount of water that enters the zone of saturation is balanced by the amount that discharges from it. Thus, withdrawal of ground water through wells commonly diverts water that might otherwise discharge naturally. By and large, the withdrawal of water provides an opportunity for increased replenishment, or decreased natural discharge, or both. However, continuing declines of water level in an aquifer, year after year, may indicate that recharge is not keeping pace with discharge, and that depletion of the supply is in prospect.

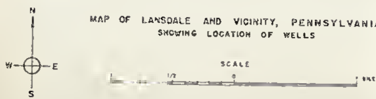
AVAILABILITY OF GROUND WATER IN THE LANSDALE AREA

Ground water in the Lansdale area is derived chiefly from the Brunswick shale. Yields of wells tapping the Brunswick shale range from about 10 gallons per minute to about 350 gallons per minute, the average being about 50 gallons per minute. Data for 120 wells are included in the table of well records (Appendix) at the end of this report and the locations are shown on plate 2. There is no apparent statistical relation between the depth of wells and their yields. The deepest well in the area, which is more than 1,100 feet deep, is reported to yield less than 20 gallons per minute. On the other hand, the highest yield, 350 gallons per minute, is reported for a well that is 367 feet deep. The fact that no single lithologic bed or zone of deposits has heretofore been identified as the principal aquifer has resulted in haphazard development of supplies and a loss of confidence in ground water as a source.

As the Brunswick shale underlies a considerable part of southeastern Pennsylvania and is the only source of water supply in much of the area, information on the occurrence and movement of water in the Brunswick shale is of great value. To obtain information on the nature of the openings that store and transmit water to wells that tap the shale, and the yield characteristics of each lithologic zone within the formation, borehole studies in 24 wells were made by the U. S. Geological Survey using geophysical techniques. These data are applicable in this and other areas underlain by the Brunswick shale and other similar rocks.



MAP OF LANSDALE AND VICINITY, PENNSYLVANIA
SHOWING LOCATION OF WELLS



EXPLANATION

°27 WELL

⊙27 OBSERVATION WELL

△27 OBSERVATION WELL WITH RECORDER

°27 LOG AVAILABLE

Exploration of Wells

Geophysical methods applied

Flow-meter tests were made in 12 of the 24 wells studied, caliper logs in 18 of the wells, and electric logs in all the wells. The flow-meter tests were made by injecting water into the wells and measuring the vertical velocity of the water at selected depths using a flow meter. The meter used was a helical turbine of the type designed in 1925 by Carl H. Au of the U. S. Geological Survey. The turbine is supported on a frame inside a cylindrical brass tube which is secured in a short length of 3-inch pipe that is lowered into the well on an electrically insulated cable. A commutator head connected through the insulated cable and a dry cell to earphones worn by the operator indicates each revolution of the meter. As the speed of rotation of the turbine is proportional to the velocity of flow, and as all flow in the test was confined to the meter tube by means of flexible flanges that closed the annular space between the meter tube and borehole wall, the rate of vertical flow at any depth could be determined.

Water injected into a well enters the same permeable zones that yield water to the well when it is pumped. The comparable hydraulic relations

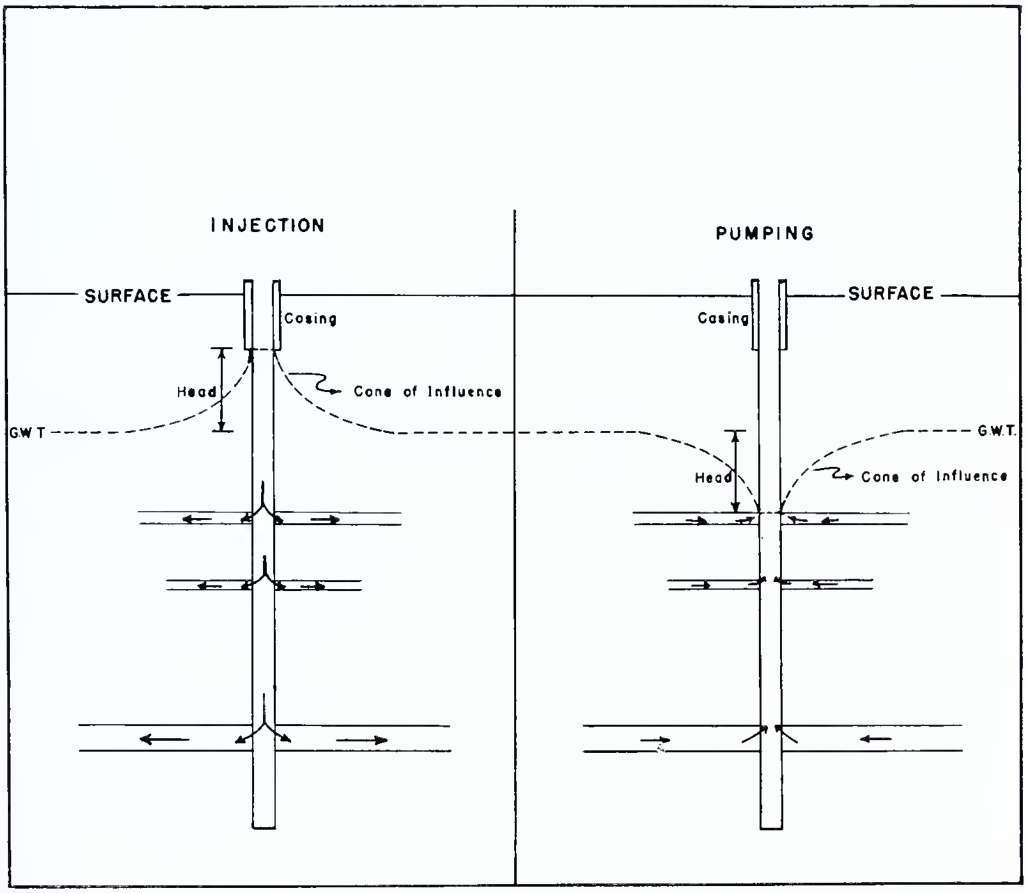


Figure 3. Diagram showing the hydraulic conditions that occur during injection of water into a well and pumping water from a well.

between aquifer and well during injection and pumping are shown on figure 3. The vertical velocity of water movement in the borehole decreases as water leaves the well and enters a permeable zone. By making measurements of the velocity at selected depths in the borehole, the rate of water injection being held constant, the position of the water-bearing zones may be ascertained. Decreases in vertical velocity above the static water level in boreholes indicate the presence of unsaturated permeable zones above the water table. The velocity is generally at a maximum near the top of the well and decreases to zero below the lowest permeable zone penetrated by the well. The velocity measurements are expressed in percent of the maximum velocity measured in the well, and plotted against depth. In this investigation the flow-meter graphs were plotted at the left of the electric logs, as illustrated in figure 4.

Caliper logs (records of borehole-diameter variation with depth) were made prior to the flow-meter tests and were used to select the depths at which the velocity of flow might be measured. Reliable flow-velocity measurements could not be made at those depths where the diameter of the borehole was shown to be significantly larger than the drilled diameter of the well because the flexible flanges on the flow-meter barrel were cut to bit size.

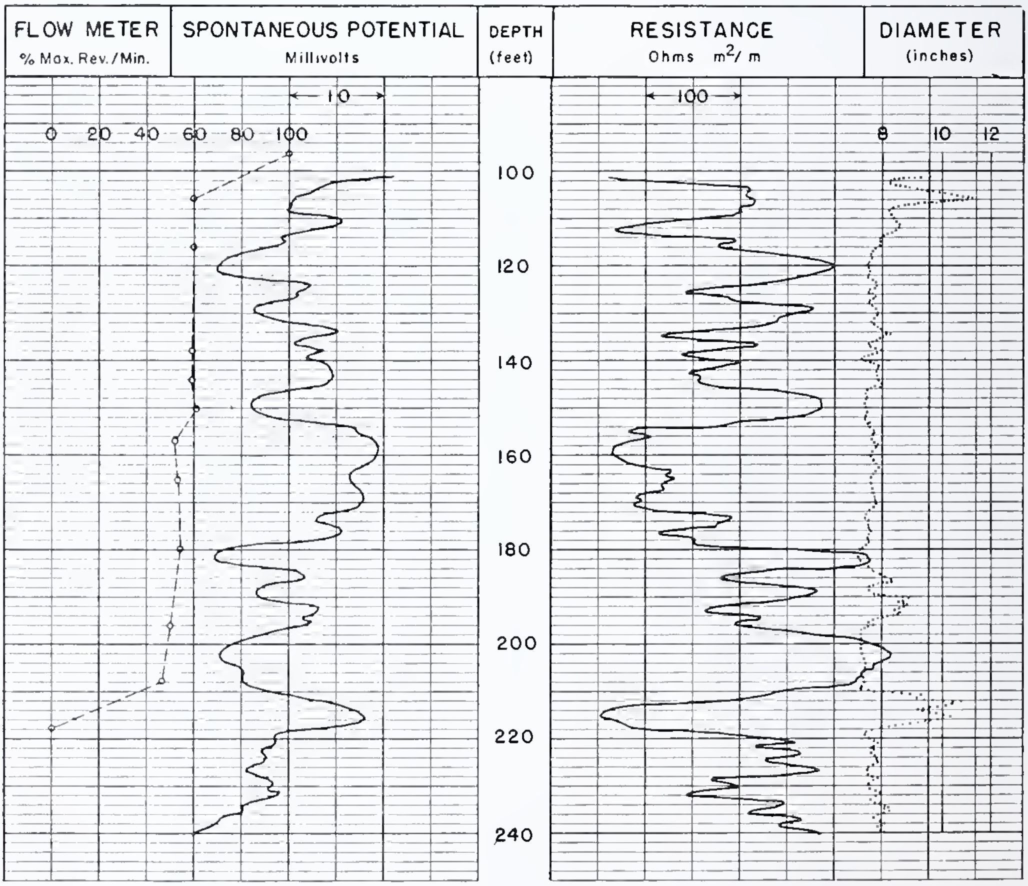
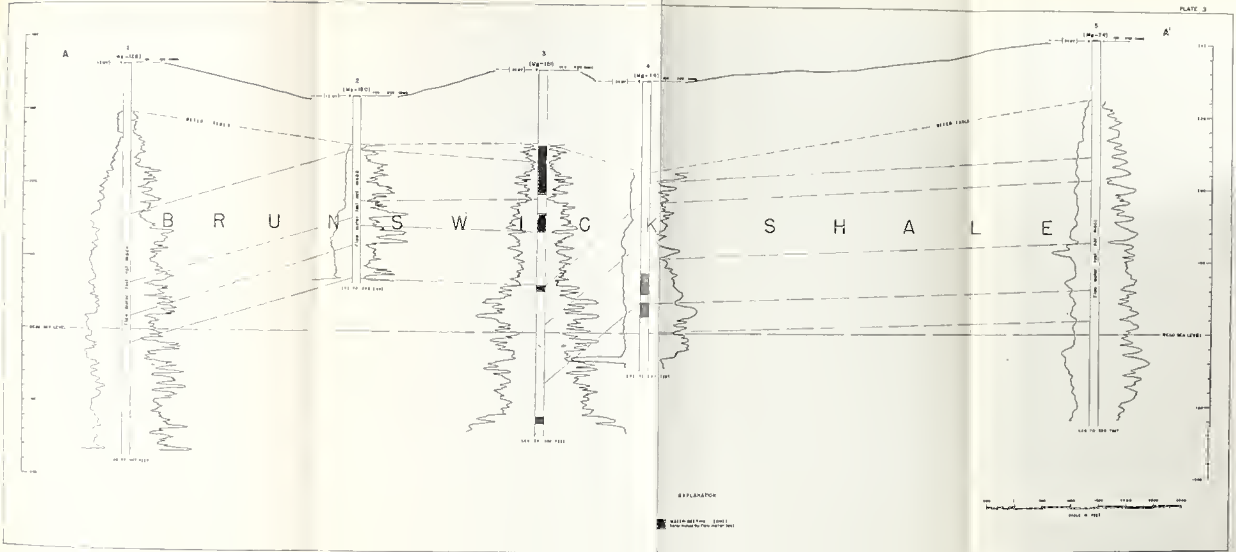


FIGURE 4. Geophysical survey of well Mg-70.



TENTATIVE CORRELATION OF ELECTRIC LOGS OF SELECTED WELLS ALONG LINE A—A AS SHOWN ON PLATE 1

Electric logs of wells were made as an aid to correlation of beds penetrated. An electric log is a record of the electrical properties of the rock layers traversed by the borehole. Most electric logs are measurements of the spontaneous potential and resistivity or resistance of the rocks.

Spontaneous electric potential is an electromotive force caused by electrochemical and electrokinetic effects present in boreholes. An electrochemical potential is generated when two fluids having different concentrations of ions come in contact. In this instance one fluid is in the borehole and the other is in the rocks penetrated by the borehole. An electrokinetic potential is produced by the movement of an electrolyte, such as slightly mineralized water, through permeable nonconductive rock material. If a borehole penetrates more than one aquifer there is likely to be a difference of pressure head between them, resulting in crossflow through the borehole. Under these conditions an electrokinetic potential is generated in the borehole opposite each of the aquifers. The magnitude of the electrokinetic potential depends on the concentration of ions in the water and the rate of water movement, and the force is in the direction of fluid movement. The algebraic sum of the potentials arising from these two sources comprises the spontaneous potential recorded on the electric log.

The resistance to the flow of an electric current between opposite faces of a unit cube of a substance is defined as its specific resistance or resistivity. In electric logging the unit of measurement is the ohm-meter. The minerals that compose most rocks have extremely high resistivity. Therefore, the factors that determine the resistivity of a water-saturated rock are its interconnected porosity, the distribution of the pores, and the salinity of the contained water. Water resistivities vary inversely with temperature, but are not altered by changes in pressure.

Spontaneous potential and resistivity are recorded continuously by commercial logging equipment at a selected linear scale with depth; the resulting curves show changes that occur in the electrical characteristics of the rock with depth, from one layer to another, as shown on figure 4. Any sequence of beds has a characteristic curve on the electric log. By comparing the electric logs of several neighboring wells that penetrate the same sequence of beds, the stratigraphic relationships between them can be established under favorable conditions. Logs of selected wells are illustrated on sections A-A′, B-B′, C-C′, plates 3-5. Because of the variable lenticular character of the beds, the logs could not be correlated with certainty.

Interpretation of well-exploration data

Geophysical methods of well exploration applied in the Lansdale area have provided useful information on the occurrence of ground water in the Brunswick shale. Some of the information is illustrated on three cross sections (pls. 3, 4, and 5). The location of wells used in the lines of section are shown on plate 2.

Flow meter logs.—The depth and thickness of water-bearing zones were determined by flow meter tests. On the basis of these tests the aquifers that underlie the Lansdale area may be divided into two classes. A water table aquifer that exhibits low permeability through a considerable thick-

ness occurs to a maximum depth of about 250 feet; below it are one or more artesian or semiartesian aquifers each generally less than 20 feet thick, which have a relatively high permeability, and occur to a maximum depth of about 600 feet.

The water table aquifer was evidenced on the flow-meter log by a small but continuous decline in the velocity of flow with depth. The fact that the velocity gradient was smooth indicates rather uniform permeability and vertical hydraulic continuity throughout this zone.

The artesian or semiartesian aquifers were evidenced by marked changes in the vertical velocity of flow below sections of the borehole in which no change of velocity occurred. A relatively higher rate of infiltration was noted in the artesian aquifers. This could be attributed to lower hydraulic head in them if their permeabilities were comparable to that of the water-table aquifer or to higher permeability, or both. A natural flow from the water table aquifer to an artesian aquifer was noted in one well (Mg-151).

Caliper logs.—Although caliper logs were made primarily to guide the flow meter tests, they were commonly found to indicate the probable depth and thickness of water-bearing zones. In most wells the caliper log recorded a significant enlargement of the borehole in the zones that were later proved to be artesian aquifers.

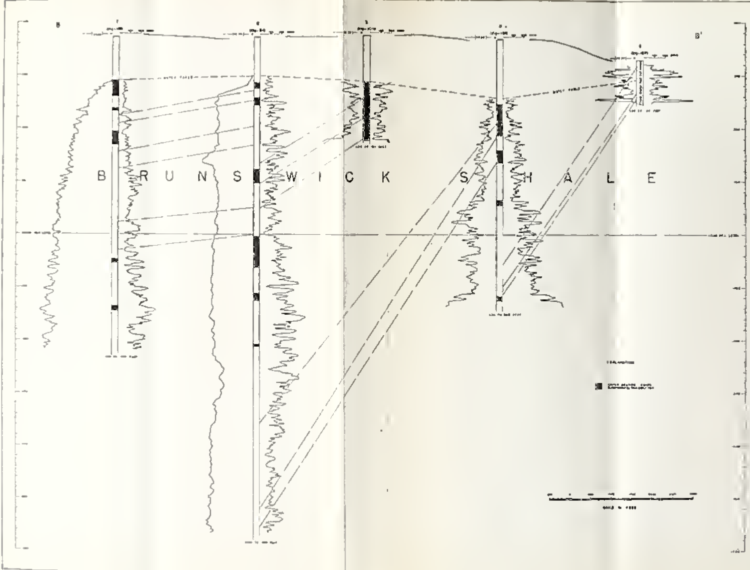
Electric logs.—Attempts were made to correlate the electric logs of wells in the Lansdale area to determine the areal extent of the water-bearing zones in the Brunswick shale. Logs of closely spaced wells could be correlated tentatively, but the greater the distance between wells the less certain was the correlation. Some of the correlations shown on plates 3, 4, and 5 are not obvious from casual inspection of the electric logs. However, thorough studies involving comparison of logs by superposition on the light table, examination of electric logs of nearby wells not shown on the lines of section, and the mapping of dip and strike in local bedrock outcrops tend to support the correlations shown.

The lack of good correlation for even moderate distances (such as 1,000 feet) is proof of the discontinuity of individual strata composing the Brunswick formation. The strata can be visualized as a series of overlapping lens-shaped beds that pinch out in all directions along the plane of bedding. Hence, a water-bearing zone formed by a selected permeable rock stratum is not likely to be very extensive.

With reference to the identification of aquifers on the electric logs two significant characteristics were noted. The water-table aquifer is characterized by a low resistivity and a moderately positive spontaneous potential. On the other hand, the artesian aquifers usually are characterized by their close association with zones having high to very high resistivity and a spontaneous potential that generally was either strongly negative or strongly positive.

The low resistivity of the water table aquifer is undoubtedly due to its relatively large water content, as compared to that of the dense, impermeable beds below. The resistivity of ground water is much less than that of dense rock, and if the water is uniformly distributed its effect upon the resistivity of a given bed is considerable even though the porosity is no more than a few percent. The gradual increase in resistance with depth

PLATE 4



TENTATIVE CORRELATION OF ELECTRIC LOGS OF SELECTED WELLS ALONG LINE B-B' AS SHOWN ON PLATE 1

shows that the interconnected porosity of the water table aquifer decreases with depth. A marked increase in resistance occurs at the base of the water table aquifer. The water-table zone was identifiable by its low resistance on the electric logs of all wells explored in the Lansdale area.

The generally high resistivity of the artesian aquifers is believed to be a result of the generally wide spacing of their water-filled voids. The voids that contain and transmit the water are apparently vertical joint fractures secondarily enlarged by solution. They comprise but a small part of the total volume of the bed, and are separated by dense, impermeable rock having high electrical resistivity. Enlargement of joint fractures by solution can occur only in beds which contain soluble material, and such beds are of limited areal and vertical extent in the Brunswick shale. It is believed that enlargement seldom exceeds 1 or 2 inches, but it is possible that voids a foot or more in width may occur where two joint systems intersect, or the abundance of soluble material in the rock favors enlargement.

HYDRAULIC CHARACTERISTICS OF AQUIFERS

The hydraulic characteristics of an aquifer determine its capacity to store and transmit water. The coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. In water table aquifers the coefficient of storage is essentially equal to the specific yield, that is, the drainable interconnected pore space. In artesian aquifers the coefficient of storage is related to the elastic properties of the aquifer skeleton and of the water itself, and is much smaller than under water-table conditions. The coefficient of transmissibility is the number of gallons of water per day that will pass through a cross-section of an aquifer 1 mile wide, with a height equal to the saturated thickness of the aquifer, under a hydraulic gradient of one foot per mile. If these coefficients are known it is possible to determine the proper spacing of wells and the optimum pumping rate, and to predict the effects of pumping on water levels.

Coefficients of transmissibility and storage are determined for an aquifer by measuring the effect of withdrawal at a known rate from a given well for a specified period of time upon water levels in other wells tapping the same aquifer at known distances from the pumped well. Mathematical formulas by which these effects are analyzed were derived from the fundamental heat equations under the direction of C. V. Theis (1935). Application of the formula is based upon the assumption that the aquifer is homogeneous in texture, of great areal extent, and hydraulically isotropic. If the aquifer being tested deviates substantially from these basic assumptions the determinations of the coefficients of transmissibility and storage are invalid unless corrections for the deviations can be made.

From the previous descriptions of the two types of aquifers that occur in the Brunswick shale it is apparent that coefficients of transmissibility and storage for them would be of little value. Determinations of the coefficients of transmissibility and storage using wells that tap more than one aquifer are not valid for any of the aquifers individually, nor for the system they compose collectively. If the water level in a well is affected by

withdrawal from another well in the same vicinity it is evident that both wells tap a common aquifer. However, if one or both of the wells tap two or more aquifers, interference data cannot be used for computation of the hydraulic characteristics of the aquifers. As this is a common occurrence in the Lansdale area, hydraulic tests serve little purpose other than to establish the areal extent of aquifers.

AQUIFER FUNCTION

Recharge

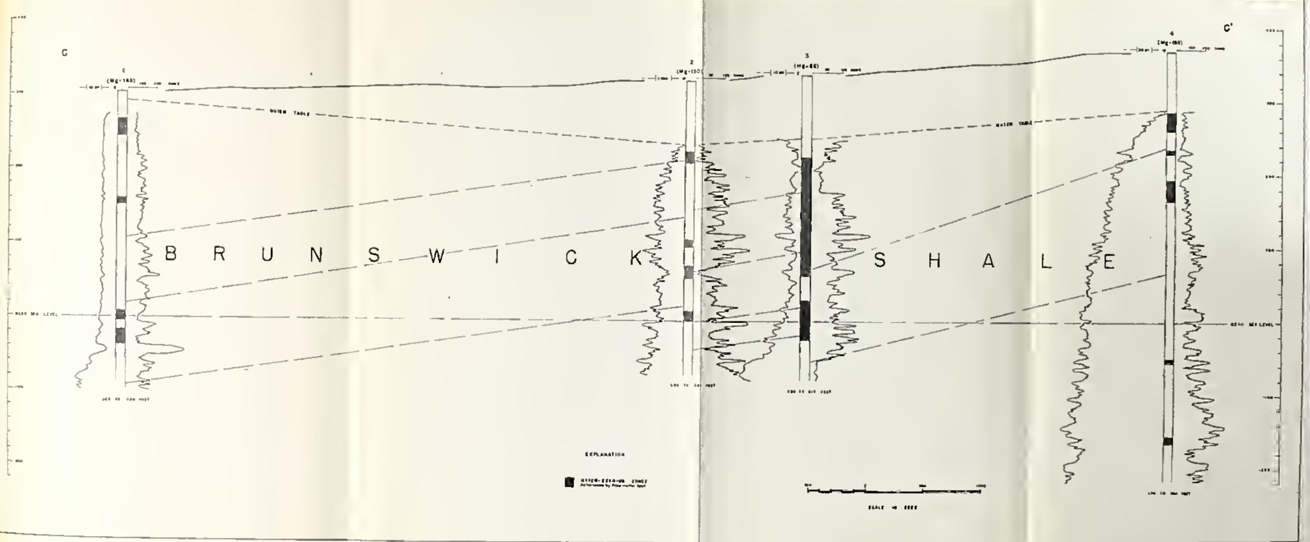
Precipitation in the Lansdale area seeps into the openings in the rocks at the land surface and a part of it migrates downward to the water table: The addition of water to that already in storage causes the water table to rise. The maximum rise of the water table in the Lansdale area occurs during the spring of the year, when the contribution of water from precipitation and snow melt is high and losses through evapotranspiration are low. As the water must move through small, tortuous openings in the rocks, which offer a great deal of resistance to the movement of water, several days or weeks may elapse before the effect of precipitation on ground-water storage can be recognized, as evidenced by rising water levels in observation wells.

The aquifers that occur below the water table zone act mainly as conduits and serve to drain the less permeable beds above them. Thus water in the artesian zone is derived from the water table zone by downward movement through joints, and the limit of the supply available is the volume in water table storage in the immediate locality.

Movement

The direction of movement of ground water is determined by the direction of slope of the water table or piezometric surface. The pattern of ground water circulation prior to the installation of wells is from areas of high elevation—hills and uplands—toward those of lower altitude, principally stream valleys. Because areas of low altitude are along the natural drainageways, ground-water movement has been concentrated beneath present-day stream valleys. Headwater areas of streams are generally less favorable for ground-water development than those downstream, for this reason, because they have been exposed to less ground-water circulation, and enlargement of fracture openings by solution has not been appreciable. In much of the Lansdale area the water table is at a depth of 50 feet or less, but in the vicinity of heavily pumped wells it may be 125 feet or more beneath the land surface. In localities remote from the centers of pumping the water table is commonly less than 20 feet below the land surface. In those localities the configuration of the water table is a subdued replica of the land surface.

The installation of wells in the Lansdale area has altered the natural gradients. The direction of movement of ground water is now a function of the locus and intensity of withdrawals. Many wells tap both water table and artesian aquifers and their withdrawals are derived in part from both sources. Because the artesian aquifers are more permeable than the water table aquifer and contain much less water in storage, the artesian pressure within them tends to decline rapidly with pumping. Conse-



TENTATIVE CORRELATION OF ELECTRIC LOGS OF SELECTED WELLS ALONG LINE C—C' AS SHOWN ON PLATE 1

quently, the downward pressure gradient from the water table zone through the semiconfining rocks to the artesian zones below is increased.

The lateral rate of ground-water movement is a function of the slope of the water table or piezometric surface and the permeability of the aquifer. As a consquence of the low permeability of the water table aquifer, the rate of lateral movement of water in it is very slow, even though the gradient may be steep. It is for this reason that water levels in wells less than half a mile from areas of heavy pumping may be relatively unaffected. The local nature of water-level declines is illustrated on plate 6, a generalized water-level contour map showing the conditions in the Lansdale area in the late summer of 1954.

Discharge

Over long periods of time the water recharged to a ground water reservoir is discharged naturally or artificially. Natural discharge takes place mainly through seeps, springs, or streams which are in effect, points of intersection between the water table and the land surface. Artificial discharge occurs through pumped or flowing wells. The withdrawal of ground water from wells in the Lansdale area decreases the amount of water that otherwise would have discharged naturally.

When more water is withdrawn from an aquifer than is recharged to it during any given period the result is a lowering of the water table or piezometric surface. If the decline persists, and especially if it accelerates over a period of several years when the rate of withdrawal is not increased, the withdrawal is obviously in excess of the replenishment, and the area is said to be overdeveloped.

In the Lansdale area the water table is highest in the spring and early summer and lowest in the fall and early winter. This is true in spite of the fact that average rates of precipitation are greatest during the months of June, July, and August. Evaporation and the transpiration of plants reduce soil moisture so much during those months that rainwater is not able to penetrate below the soil and recharge of ground-water is negligible. Also, withdrawals from wells are generally greater during the latter part of the summer when the rate of recharge is at a minimum.

Except in the immediate vicinity of the borough of Lansdale and in the area between Lansdale and North Wales the general level of the water table has declined very little as a result of withdrawals from storage during the past decade. However, marked declines have occurred in the vicinity of closely spaced wells installed during the past few years. (See hydrographs, pl. 7.)

The total daily withdrawal from wells in the Lansdale area has not been inventoried, but records for about 80 wells now in use indicate that about 5 million gallons a day is pumped during the summer months. The yields of new wells generally decline 50 to 70 percent from their initial discharge rates during the first year of operation, and new wells located within about 1,500 feet of existing wells reduce significantly the yields of the older wells.

Drought years, which result in accelerated rates of withdrawal from wells, are also periods of reduced recharge. The combined effects cause critical declines in water levels and reduced yields from wells. Because

PLATE 6

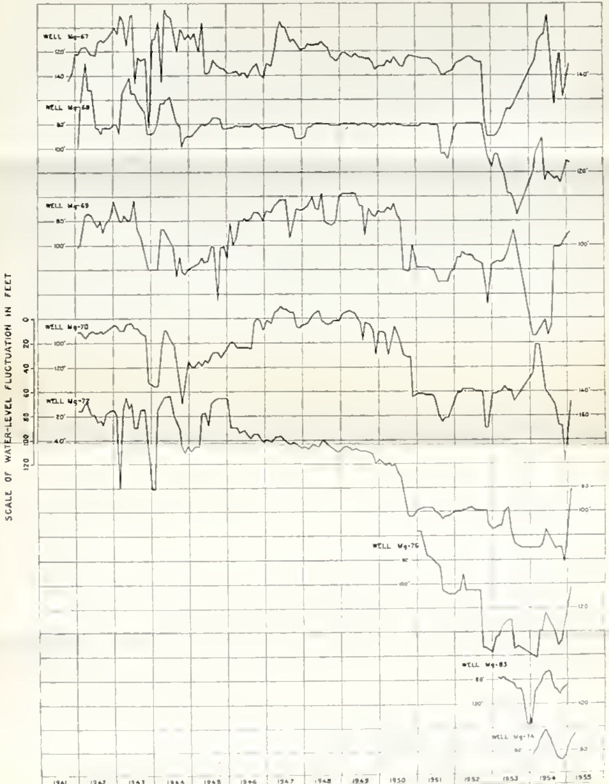
N
W E
S

WATER-LEVEL CONTOUR MAP OF THE LANSDALE AREA
SHOWING
ALTITUDE OF THE WATER TABLE IN LATE SUMMER 1954

SCALE
1 ½ 0 1 MILE

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

PLATE 7



HYDROGRAPHS OF SELECTED WELLS IN THE LANSDALE AREA, MONTGOMERY COUNTY, PENNSYLVANIA

available ground-water storage is not great the annual increment to storage from precipitation must approximate the annual withdrawal from wells if depletion is to be avoided. Prolonged drought would therefore pose a serious threat to the water supplies of the Lansdale area. The water shortage that occurred in the late summer and fall of 1953 is indicative of the conditions that might prevail.

CHEMICAL QUALITY OF THE GROUND WATER

Ground water from wells that tap the Brunswick shale in the Lansdale area has a relatively low dissolved solids content, is moderately hard, and is slightly acidic. Its iron content is negligible, and its sulfate content (which contributes to non-carbonate or permanent hardness) is not excessive. According to the standards of the U. S. Public Health Service the water is acceptable for use in public supply without treatment.

Although the silica content of the water is not high, it would give trouble if used in high-pressure steam boilers. For most other industrial uses the water would be satisfactory. Its temperature ranges from about 50° F for shallow wells (100-150 feet deep) to about 55° F for deep wells (400-500 feet deep).

Chemical analyses of representative waters from the Brunswick shale are given in the following table.

TABLE 1. Chemical analyses of ground water from the Brunswick shale in the Lansdale area.

Analyses by Geological Survey, United States Department of the Interior
(Parts per million)

	Mg-52	†Mg-62	Mg-76
DATE OF COLLECTION	9/25/25	9/28/25	2/21/52
Silica (SiO_2)	18	32	21
Iron (Fe)	.06	.05	.01
Calcium (Ca)	47	36	24
Magnesium (Mg)	17	15	20
Sodium (Na)	9.4	11	
Potassium (K)	2.1	1.8	5.1
Bicarbonate (HCO_3)	*194	*173	150
Sulfate (SO_4)	23	15	22
Chloride (Cl)	13	8.0	5
Fluoride (F)			
Nitrate (NO_3)	7.5	2.5	.4
Dissolved solids	232	201	
Total hardness as $CaCO_3$	187	152	142
Specific conductance ($K x 10^5$ at 25°C.)			321
pH			6.4
Temperature	54°F.		55°F.

* Includes equivalent of small amount of carbonate.
† Composite sample from 3 wells (Mg-62, 63, 64).

Development of Additional Ground-Water Supplies

In the development of additional ground-water supplies in the Lansdale area consideration should be given to the several factors described above. The most favorable localities for drilling new wells of high yield in the Lansdale area are near streams or springs remote from other heavily pumped wells. There are several such localities within a 5-mile radius of Lansdale. To the south and west from Lansdale the valleys of the north and south branches of Towamencin Creek offer possibilities. Another favorable locality, northeast of Lansdale, is the valley of the branch of Neshaminy Creek that parallels Line Road.

New wells should be spaced sufficiently far apart to reduce the effect of interference between wells. The proper spacing will vary from one locality to another, as it depends on the hydraulic characteristics of the formation. Wells less than 1,500 feet apart have shown appreciable mutual interference.

Heavy and prolonged pumping of individual wells in the Lansdale area results in considerable reduction of specific capacity. As water levels in a water-table aquifer are lowered appreciably, the effective thickness—and hence the transmissibility of the aquifer—are diminished, resulting in decreased yields from wells.

SUMMARY

In summary, ground water occurs in the Brunswick shale near the surface in a water table aquifer and at greater depth in artesian aquifers. The water-table aquifer comprises a system of fracture openings that are usually larger and more numerous at shallow depths than at greater depths. The artesian aquifers consist of zones of solution openings that are controlled by the local structure and stratigraphy of the formation. They may occur at any depth that is accessible to circulating ground water. The formation of solution openings requires that rocks containing soluble material be intersected by open fractures. All fractures are closed by rock pressure at depth and artesian aquifers are rarely found in the Brunswick shale below a depth of about 600 feet.

The aquifers at depth, formed by solution, are erratic in their occurrence and limited in their areal extent, and their presence can be determined only by test drilling. The best wells usually obtain their supply from both vertical fracture openings in the upper water table zone, and one or more permeable artesian zones at depth. The most favorable areas for the development of additional supplies are near streams and remote from heavily pumped wells.

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APPENDIX

Records of Wells in the Lansdale Area

Numbers correspond with those on Plate 2.
Type of well: Drl, drilled.
Aquifer: Trb, Brunswick shale; Trl, Lockatong formation.

Use of water: Abd, abandoned; Dom, domestic; Ind, industrial; Obs, observation; PS, public supply; S, standby; T, Test; U, unused.

Well Number	Location Number	Owner	Driller	Altitude	Type of well	Diameter (inches)	Depth (feet)	Depth of casing (feet)	Aquifer	Water Level (feet)	Date of measurement	Yield (gpm)	Use
46	J22b-2654	North Wales Water Auth.		440	Drl	6	500		Trl			0	Abd
47	J22b-2652	North Wales Water Auth.	Marwin	389	Drl	8	129	20	Trb			45	Abd
48	J22b-2652	North Wales Water Auth.	Raun & Co.	390	Drl	8	104	20	Trb	84.0	7-1-54		Abd
49	J22b-2652	North Wales Water Auth.	Ridpath & Potter	391	Drl	8	158	45	Trb			100	S
50	J22b-2949	North Wales Water Auth.	Ridpath & Potter	355	Drl	8	448	100	Trb			80	Abd
51	J22b-2652	North Wales Water Auth.	Ridpath & Potter	400	Drl	8	800		Trl	Dry	1909		Abd
52	J22b-2948	North Wales Water Auth.	Ridpath & Potter	350	Drl	8	350	30	Trb			80	PS
53	J22b-2353	North Wales Water Auth.	Bollinger	388	Drl	8	350		Trb			30	Abd
54	J22b-2353	North Wales Water Auth.		392	Drl	8	500		Trl	Dry	1910		Abd
55	J22b-2847	North Wales Water Auth.	Bollinger	328	Drl	10-8	300	77	Trb			240	PS
56	J22b-2444	North Wales Water Auth.	Stothoff	325	Drl	14-10	384½	72	Trb	0.0	4-23-45	280	PS
57	J22b-1239	Martin Century Farms	Parente Bros.	320	Drl	8	201	30	Trb	45	6-20-45	95	Ind
58	J22b-1239	Martin Century Farms	Parente Bros.	322	Drl	8	225	30	Trb	86	6-21-46	95	Ind
59	J22b-1239	Martin Century Farms	Parente Bros.	320	Drl	8	198	30	Trb	53	6-25-46	95	Ind
60	J22b-0649	Lansdale Municipal Auth.		366	Drl	8	312	80	Trb			8	U
61	J22b-0649	Lansdale Municipal Auth.		366	Drl	8	392		Trb	78.9	8-6-54	8	U
62	J22b-0649	Lansdale Municipal Auth.		366	Drl	8	388	22	Trb	75.5	8-6-54	8	U
63	J22b-0649	Lansdale Municipal Auth.		366	Drl	8	400	120	Trb	78	3-1-43	18	U
64	J22b-0649	Lansdale Municipal Auth.		366	Drl	8	1108	18	Trb	83.2	11-4-54	8	U
65	J22b-0751	Lansdale Municipal Auth.		436	Drl	8	436	34	Trb	80.2	11-14-54		Abd
66	J22b-0751	Lansdale Municipal Auth.	Bollinger	376.2	Drl	8	378		Trb	92	3-1-47	60	S
67	J22b-0044	Lansdale Municipal Auth.	Bollinger	328.5	Drl	8	292		Trb	132	3-1-47	57	PS
68	J22b-0841	Lansdale Municipal Auth.	Bollinger	321.8	Drl	8	500		Trb	83	1-31-47	79	PS
69	J22b-0640	Lansdale Municipal Auth.	Stothoff	328	Drl	12-8	264	40	Trb	73	1-31-47	39	S
70	J22b-0755	Lansdale Municipal Auth.	Stothoff	420.9	Drl	10-8	391	36	Trb	84	1-31-47	28	S
71	J22b-0553	Lansdale Municipal Auth.	Stothoff	406.8	Drl	12-8	285	43	Trb	70	1-31-47	46	U
72	J22b-0952	Lansdale Municipal Auth.	Stothoff	352.8	Drl	16-10	306	44.5	Trb	42	3-1-47	128	PS
73	J22b-1257	Lansdale Municipal Auth.	Stothoff	371.4	Drl	14-10	325	45	Trb	46	3-1-47	197	PS
74	J22b-0563	Lansdale Municipal Auth.	Stothoff	403.1	Drl	12-10	546		Trb	48	2-24-48	50	U
75	J22b-0860	Lansdale Municipal Auth.	Stothoff	384	Drl	12-10	399.5	40.3	Trb	57	9-17-48	175	PS

Records of Wells in the Lansdale Area (continued)

Well Number	Location Number	Owner	Driller	Altitude	Type of well	Diameter (inches)	Depth (feet)	Depth of casing (feet)	Aquifer	Water Level (feet)	Date of measurement	Yield (gpm)	Use
76	J22b-1652	Lansdale Municipal Auth.	Stothoff	341	Drl	12-10	387.5	37	Trb	23	7-18-49	240	PS
77	J22b-1354	Lansdale Municipal Auth.	Stothoff	353.8	Drl	12-10	404		Trb	30	7-3-51	328	PS
78	J22b-1059	Lansdale Municipal Auth.	Stothoff	375	Drl	12-10	430.5	41	Trb	126	10-31-52	173	PS
79	J22b-0246	Lansdale Boro Electric Co.	Alexander	350	Drl	8	279		Trb	109	1-14-54	20	Ind
80	J22b-0143	Lansdale Boro Electric Co.	Bollinger	325	Drl	8	320		Trb	60	1946	80	Ind
81	J22b-0346	Lansdale Boro Electric Co.	Bollinger	340	Drl	8	350		Trb	45	1946	60	Ind
82	H22d-8145	Lansdale Boro Sewage	Bollinger	375	Drl	8	375		Trb	20	1947	18	Ind
83	J22b-0045	Lansdale Forest Products Co.	Bollinger	330	Drl	8	425		Trb	73.7	11-18-52		Obs
84	H22d-9145	Lansdale Forest Products Co.	Bollinger	330	Drl	8-6	231		Trb	63	8/47	11	Ind
85	J22b-0846	Lansdale Ice & Storage		360	Drl	8	615		Trb	65.7	11-18-52		Abd
86	J22b-0846	Lansdale Ice & Storage		355	Drl	8	300		Trb	60	11-18-52		Abd
87	J22b-0846	Lansdale Ice & Storage	Shaw	350	Drl	6	305		Trb	60	1946	35	Ind
88	J22b-0847	Lansdale Ice & Storage	Bollinger	450	Drl	10-8-6	450		Trb	60	1946	40	Ind
89	J22b-1548	Lansdale Tube Co.	Phila. Drlg. Co.	382	Drl	8	400	40	Trb	50	9-20-49	96	Ind
90	J22b-1648	Lansdale Tube Co.	Phila. Drlg. Co.	375	Drl	8	500	46	Trb	57	1-17-51	165	Ind
121	J22b-2241	E. C. Geiger		358	Drl	6	100		Trb	71.6	11-30-53	40	Abd
122	J22b-2240	Sharp & Dohme, Inc.		368	Drl	8	247		Trb	40	1947	75	S
123	J22b-2539	Sharp & Dohme, Inc.	Bollinger	362	Drl	10-6	502		Trb	33.8	5-14-51	15	Obs
124	J22b-2740	Sharp & Dohme, Inc.	Lauman	328.6	Drl	12	300		Trb			350	Ind
125	J22b-2538	Sharp & Dohme, Inc.	Lauman	357.1	Drl	12	300		Trb	64	10-28-54	140	Obs
126	J22b-2641	Sharp & Dohme, Inc.	Lauman	338.3	Drl	12	241		Trb	167	5-14-51	275	Ind
127	J22b-2137	Sharp & Dohme, Inc.	Lauman	351.0	Drl	12-10	300		Trb	52.9	11-3-53	130	Obs
128	J22b-2039	Sharp & Dohme, Inc.	Lauman	352.5	Drl	12-10	300		Trb	58.0	11-3-53	395	Obs
129	J22b-2534	Sharp & Dohme, Inc.	Lauman	358.7	Drl	12-10	269		Trb	58.6	11-3-53	30	Obs
130	J22b-2342	Sharp & Dohme, Inc.	Lauman	339	Drl	12	300	16	Trb	65.8	11-3-53	320	Ind
134	H22d-6234	Werner Foundry	Flaherty	323	Drl	6	106.5		Trb			10	Ind
135	J22b-1747	Lansdale Tube Co.	Phila. Drlg. Co.	370	Drl	12-8-6	500		Trb	85	8-17-53	200	Ind
136	J22b-0657	St Mary's Inst.		435	Dug	24	23.5	24	Trb	19.6	2-25-54		Obs
137	J22b-0848	Interstate Hosiery		365	Drl								Abd
138	J22b-0849	Interstate Hosiery		370	Drl	10-10			Trb			50	Ind

Records of Wells in the Lansdale Area (continued)

Well Number	Location Number	Owner	Driller	Altitude	Type of well	Diameter (inches)	Depth (feet)	Depth of casing (feet)	Aquifer	Water Level (feet)	Date of measurement	Yield (gpm)	Use
139	J22b-0849	Interstate Hosiery		370	Drl				Trb			70	Ind
140	J22b-1339	Martin Century	Stothoff	293	Drl	8	237	30	Trb	17.2	2-25-54		Ind
141	H22d-0657	St Mary's Inst.		435	Drl	6			Trb				Abd
142	J22b-0436	Lansdale Municipal Auth.	Stothoff	310	Drl	12	503	41	Trb	15.0	6-9-54	60	PS
143	J22b-0435	Lansdale Municipal Auth.	Stothoff	295	Drl	12	400	30	Trb	8.0	6-9-54	270	PS
144	J22b-1047	Andale Corporation		368	Drl	8	197.6	6	Trb	84.5	2-27-41	6.3	Abd
147	J22b-1649	Lansdale Tube Co.	Phila. Drlg. Co.	370	Drl	8	500		Trb	85	8-26-54	220	Ind
149	J22b-0657	St Mary's Inst		430	Drl	8	83		Trb	17	7-2-54		Obs
150	J22b-0043	J. W. Rex Co.	Bollinger	320	Drl	10	403		Trb	70	8-5-54	58	Ind
151	J22b-1749	Lansdale Tube Co.	Phila. Drlg. Co.	365	Drl	8	500	78	Trb	100	11-6-54	200	Ind
154	J22b-0248	Arcadia Hosiery	Scazetts	353	Drl	6	353		Trb	85	1934	20	Ind
155	H22d-8551	Penndale Inc.	Ridpath & Potter	367	Drl	8	600	30	Trb	79	8-24-54	41	Ind
156	H22d-8546	Perkins Glue Co.		340	Drl	6	206		Trb	30	1909	40	Ind
157	H22d-8544	F. M. Weaver & Co.	Bollinger	315	Drl	8	285	46.6	Trb	50	6/50	115	Ind
158	H22d-8544	F. M. Weaver & Co.	Bollinger	317	Drl	6			Trb	Dry	1950		Abd
159	H22d-8445	Nyce-Crete Co.		325	Drl	6			Trb				Abd
160	H22d-8445	Brook Rota Meter Co.		325	Drl				Trb			10	Abd
161	J22b-0142	Dexdale Hosiery Co.	Bollinger	340	Drl	6	201	30	Trb	125	2-22-54	21	Ind
162	J22b-0142	Dexdale Hosiery Co.	Bollinger	340	Drl	10	761	30	Trb			30	Ind
163	J22b-0142	Dexdale Hosiery Co.	Bollinger	340	Drl	8	301	30	Trb			15	Ind
164	J22b-0242	Dexdale Hosiery Co.	Bollinger	342	Drl	8	405	30	Trb			18	Ind
165	J22b-0345	K & K Laundry Co.	Wiley	335	Drl	8	400		Trb	90	1946	50	Ind
166	J22b-0345	K & K Laundry Co.		335	Drl	6	147		Trb			5	Abd
167	J22b-2349	Leeds & Northrup	Ridpath & Potter	350	Drl	4	80	6	Trb			30	U
168	J22b-2245	Leeds & Northrup	Ridpath & Potter	325	Drl	4	77		Trb			30	U
169	J22b-2445	Leeds & Northrup	Ridpath & Potter	335	Drl	4	150		Trb	80.0	9-15-54	30	Obs
170	J22b-2445	Tritzel Bakery		350	Drl	6	350		Trb			14	U
171	J22b-1748	Precision Tube Co.	Phila. Drlg. Co.	363	Drl	8	500	40	Trb	117.5	10-12-54	100	Ind
172	J22b-2848	King Foundries	Schroeder	345	Drl	6	105		Trb			95	Ind
173	J22b-2050	Kleen Products			Drl	6	90	20	Trb	Dry	10-12-54	20	Abd

Records of Wells in the Lansdale Area (continued)

Well Number	Location Number	Owner	Driller	Altitude	Type of well	Diameter (inches)	Depth (feet)	Depth of casing (feet)	Aquifer	Water Level (feet)	Date of measurement	Yield (gpm)	Use
174	J22b-2049	Kleen Products	Findly & Son	348	Drl	6	144.5	34	Trb	25	4-8-50	36	Ind
175	J22b-2150	Kleen Products		358	Drl	6	160		Trb	Dry	10-12-54		Abd
176	J22b-2151	Sam Scott	Pat Flaherty	352	Drl	8	94	12	Trb	28	1941	10?	Dom
177	J22b-2251	Ellis Stump	Pat Flaherty	350	Drl	8	96	10	Trb	32	9/50	300	Dom
178	J22b-2150	North Wales Foundry		360	Drl	6	140		Trb	92.0	11-8-54	20	Ind
179	J22b-2350	Leeds & Northrup		358	Drl	6	126	60	Trb	10	1/47	100	U
180	J22b-2246	Leeds & Northrup	Ridpath & Potter	325	Dr.	6	250		Trb	65	11-2-54	100	T
181	J22b-1348	Lansdale Brick Co.		372	Drl	6	88		Trb	Dry	11/53	30	Abd
182	J22b-0364	Sanford Ulmer	Harry L. Garges	430	Drl	6	125	24	Trb	69.9	11-9-54	12	Dom
183	J22b-0365	Sanford Ulmer	Harry L. Garges	430	Drl	6	125	24	Trb	72.3	11-9-54	10	Dom
184	J22b-0262	Sanford Ulmer	Harry L. Garges	440	Drl	6	180	24	Trb	75.2	11-9-54	10	Dom
185	J22b-0548	Music Hall Theatre		355	Drl		365		Trb			165	Ind
186	H22d-7065	Link-Belt		270	Drl		300		Trb			65	Ind
187	H22d-7065	Link-Belt	Andrew J. Nicholas	270	Drl		300		Trb			85	Ind
188	H22d-6965	Link-Belt		270	Drl		300		Trb			105	Ind
189	H22d-6742	Hatfield Boro		320	Drl	14-10	200	65	Trb	13	8-16-33	150	PS
190	H22d-6638	Hatfield Boro	John T. Campbell	350	Drl	8	202	36	Trb			150	PS
191	H22d-6242	Hatfield Boro	Stothoff	345	Drl				Trb				PS
192	H22d-8336	Hendrick's Dairy	Stothoff	322	Drl	10	352	10	Trb			50	Ind
193	H22d-8336	Hendrick's Dairy		325	Drl	6	102		Trb	49	11/46	10	Dom
194	H22d-7742	Edward Hilpert		325	Drl	6	100		Trb	10	11-10-54	18	Ind
195	H22d-7642	Edward Hilpert		325	Drl	6	75	40	Trb	12	11-10-54	29	Ind
196	H22d-7642	Edward Hilpert		325	Drl		117.8		Trb	14.1	11-10-54	20	Obs
197	H22d-7428	Hatfield Packing Co		295	Drl	6	181		Trb	12-15	1946	55	Ind
198	H22d-7328	Hatfield Packing Co.	Parente Bros.	300	Drl		200		Trb			60	Ind
199	H23b-8400	L. Weiss & Son		395	Drl	8	54		Trb	15	1926	35	Ind
200	H22d-6742	Hatfield Boro		320	Drl	6	115	25	Trb			50	S
202	J22b-1751	Lansdale Municipal Auth.	Stothoff	350	Drl	12	645		Trb	54	1-19-55	282	PS
203	J22b-2443	North Wales Municipal Auth.	Kohl Bros.	315	Drl	8	450	27	Trb	12	1-17-55	210	PS